FORM PTO-1390 (REV. 10-2003) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY 'S DOCKET NUMBER: Tan Rajah Cheah 010202

U.S. APPLICATION NO. (If known, see 37 CFR 1.5): 10/500565

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/SG02/000091	14 May 2002 (14.05.2002)	14 May 2001 (14.05.2001)

TITLE OF INVENTION
BIODEGRADABLE POLYPHOSPHORAMIDATES FOR CONTROLLED RELEASE OF BIOACTIVE SUBSTANCES

APPLICANT(S) FOR DO/EO/US
WANG, Jun; MAO, Hai-Quan; LEONG, Kam Weng

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. [X] The US has been elected (Article 31).
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is attached hereto (required only if not communicated by the International Bureau).
   b. [X] has been communicated by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. [ ] is attached hereto.
   b. [ ] has been previously submitted under 35 U.S.C. 154(d)(4).
7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [X] are attached hereto (required only if not communicated by the International Bureau).
   b. [X] have been communicated by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). unexecuted
10. [ ] An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [ ] A preliminary amendment.
14. [ ] An Application Data Sheet under 37 CFR 1.76.
15. [ ] A substitute specification.
16. [ ] A power of attorney and/or change of address letter.
17. [ ] A computer-readable form of the sequence listing in accordance with PCT Rule 13*ter*.2 and 37 CFR 1.821 - 1.825.
18. [ ] A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. [ ] A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. [X] Other items or information:
    - copy of International Application as filed
    - copy of International Application with Amendment to the IPER incorporated
    - extra set of drawings
    - International Search Report PCT/ISA/210
    - International Preliminary Examination Report PCT/IPEA/409

U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/500565	INTERNATIONAL APPLICATION NO. PCT/SG02/000091	ATTORNEY'S DOCKET NUMBER Tan Rajah Cheah 010202

21. ☒ The following fees are submitted:	CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1080.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $920.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $770.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) $730.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 1,080.00	
Surcharge of $130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 130.00	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	27 - 20 =	7	x $18.00	$ 126.00	
Independent claims	5 - 3 =	2	x $86.00	$ 172.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $290.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 1,508.00	
☒ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$ 754.00	
SUBTOTAL =				$ 754.00	
Processing fee of $130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$	
TOTAL NATIONAL FEE =				$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 754.00	
				Amount to be refunded:	$
				charged:	$

a. ☐ A check in the amount of $ _____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 50-2638 in the amount of $ 754.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 50-2638 . A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Claude Nassif
SIGNATURE

Claude Nassif
NAME

52,061
REGISTRATION NUMBER

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Express Mail Label No.	EV 311274159 US	**Group Art Unit:**	
Applicant(s):	Jun WANG; Hai-Quan MAO; Kam Weng LEONG	**Examiner:**	
Filing Date:	November 13, 2003	**Docket No.**	71419-010202
Title: Biodegradable Polyphosphoramidates for Controlled Release of Bioactive Substances		**Customer No.**	33717

FILING INQUIRY

Dear Sir:

Applicants have not received any communication from the U.S. Patent and Trademark Office since the filing of the above U.S. National Phase Application on November 13, 2003. The confirmation postcard enclosed with the filed application has not been received.

Enclosed please find the following:

- Tracking Confirmation from U.S. Postal Services;
- copy of Express Mail Receipt dated by U.S. Postal Services; and
- complete application as filed on November 13, 2003.

Please send a Filing Receipt to the Correspondence Address below as soon as possible.

Respectfully submitted,

GREENBERG TRAURIG, LLP

Date June 21, 2004

By _____
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BIODEGRADABLE POLYPHOSPHORAMIDATES FOR CONTROLLED RELEASE OF BIOACTIVE SUBSTANCES

This application claims the benefit of U.S. Provisional Application Serial No. 60/290,833 filed May 14, 2001, the teachings of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to biodegradable polymer compositions, in particular those containing both phosphoester linkages in the polymer backbone and chargeable groups linked to the backbone through a P-N bond. The polymers of the invention are useful for drug and gene delivery, particularly as carriers for gene therapy and for the delivery of protein drugs.

2. Background

Gene therapy has been progressively developed with the hope that it will be an integral part of medical modalities in the future. Gene delivery system is one of the key components in gene medicine, which directs the gene expression plasmids to the specific locations within the body. The control of gene expression is achieved by influencing the distribution and stability of plasmids *in vivo* and the access of the plasmids to the target cells, and affecting the intracellular trafficking steps of the plasmids (*Mahato, et al., 1999, Pharmaceutical perspectives of nonviral gene therapy, Adv. Genet. 41: 95-156*). An ideal gene delivery carrier should be bioabsorable, non-toxic, non-immunogenic, stable during storage and after administration, able to access target cells, and efficient in aiding gene expression. As many studies demonstrated, the limitations of viral vectors make synthetic vectors an attractive alternative. Advantages of non-viral vectors include non-immunogenicity, low acute toxicity, versatility, reproducibility and feasibility to be

produced on a large scale. Cationic liposome and cationic polymers are the two major types of non-viral gene delivery carriers. Cationic lipids self assemble into organized structures include micelles, plannar bilayer sheets, and lamellar vesicles. Through the condensation process, liposomes and cationic polymers form complexes with DNA due to charge interaction. A large variety of liposomal compositions have been developed for gene delivery (*Chesnoy and Huang, 2000, Structure and function of lipid-DNA complexes for gene delivery, Annu. Rev. Biophys. Biomol. Struct. 29: 27-47*). An effective liposome vector generally composed of a positively charged lipid (e.g. cationic derivatives of cholesterol and diacyl glycerol, quaternary ammonium detergents, lipid derivatives of polyamines, etc.) and a neutral helper lipid (e.g. dioleoyl phosphatidylethanolamine (DOPE) or dioleoyl phosphotidylcholine (DOPC)). Despite early excitement, there are serious limitations to most cationic lipid systems. Several observations have suggested that liposomal systems are relatively unstable after the administration. Significant toxicity upon repeated use has been shown to be associated to liposomal vectors, especially the fusogenic phospholipid (neutral lipid), include the down regulation of PKC dependent immunomodulator synthesis, macrophage toxicity, neurotoxicity and acute pulmonary inflammation (*Filion and Phillips, 1998, Major limitations in the use of cationic liposomes for DNA delivery, Int. J. Pharm. 162: 159-170*).

Because of the limitations of viral vectors, cationic lipids, cationic polymers as the basis of gene delivery systems have gained increasing attention recently. A number of polycations have been reported to effect transfection of DNA, including poly-L-lysine, poly-L-ornithine, poly(4-hydroxy-L-proline ester), polyiminocarbonate containing cyclodextrin, poly[α-(4-aminobutyl)-L-glycolic acid], polyamidoamines, polyamidoamine dendrimers, chitosan, polyethylenimine, poly(2-dimethylaminoethyl methacrylate), etc. Significant progress has been made in the development of polymer based systems, especially biodegradable polymers that have lower toxicity and can mediate gene transfection via condensing DNA into small particles and protecting DNA from enzymatic degradation. Nevertheless, searching for a safer and more efficient gene carrier still remains a major challenge in the field of non-viral gene delivery.

SUMMARY OF THE INVENTION

The invention provides positively chargeable biodegradable polymers that comprises at least one phosphoester linkage in the polymer backbone and at least one positively chargeable group wherein the positively chargeable group is a substitutent of a side chain attached to the polymer backbone through a phosphoramidate linkage, e.g., a P-N bond.

The invention further provides positively chargeable biodegradable polymer compositions comprising:

(a) at least one biologically active substance; and

(b) A positively chargeable biodegradable polymer comprising at least one phosphoester linkage in the polymer backbone and at least one positively chargeable group wherein the positively chargeable group is a substituent of a side chain attached to the polymer backbone through a phosphoramidate linkage.

The invention additionally provides a method of preparing a positively chargeable biodegradable polymers. The method comprising the steps of:

polymerizing at least two monomers to form a polymer with at least one phosphoester linkage in the polymer backbone;

reacting the polymer with a primary or secondary amine having a positively chargeable group or a substituent that can be functionalized to a positively chargeable group under conditions conducive to the formation of a positively chargeable biodegradable polymer comprising at least one phosphoester linkage in the polymer backbone and at least one positively chargeable group wherein the positively chargeable group is a substitutent of a side chain attached to the polymer backbone through a phosphoramidate linkage.

The invention provides a method of preparing a positively chargeable biodegradable polymer composition. The method comprises the steps of:

providing a positively chargeable biodegradable polymer comprising at least one phosphoester linkage in the polymer backbone and at least one positively chargeable

group wherein the positively chargeable group is a substitutent of a side chain attached to the polymer backbone through a phosphoramidate linkage.

contacting the positively chargeable biodegradable polymer with a biologically active substance under conditions conducive to the formation of a complex, e.g., a composition, comprising the positively chargeable biodegradable polymer and the biologically active substance.

The invention also provides for the controlled release of a biologically active substance. The method comprises the steps of:

providing a positively chargeable biodegradable polymer composition comprising:

(a) at least one biologically active substance; and

(b) A positively chargeable biodegradable polymer comprising at least one phosphoester linkage in the polymer backbone and at least one positively chargeable group wherein the positively chargeable group is a substituent of a side chain attached to the polymer backbone through a phosphoramidate linkage;

contacting the composition with a biological fluid, cell or tissue under conditions conducive to the delivery of at least a portion of the biologically active substance to the biological fluid, cell or tissue.

The invention further provides methods for gene transfection using the controlled release methods and the positively chargeable biodegradable polymer composition comprising a DNA sequence, a gene or a gene fragment, to deliver a DNA sequence, a gene or a gene fragment to a specified tissue target in a patient. Gene transfection methods of the invention are suitable for use in treatment of any disease or disorder which is currently treatable by gene therapy or is contemplated as a disease or disorder suitable for treatment by gene therapy in the for future. Gene transfection methods of the invention comprise the steps of

providing a positively chargeable biodegradable polymer composition comprising:

(a) at least one DNA fragment, gene or gene fragment; and

(b) a positively chargeable biodegradable polymer comprising at least one phosphoester linkage in the polymer backbone and at least one

positively chargeable group wherein the positively chargeable group is a substituent of a side chain attached to the polymer backbone through a phosphoramidate linkage;

contacting the composition with a biological fluid, cell or tissue under conditions conducive to the delivery of at least a portion of the DNA sequence, gene or gene fragment to the biological fluid, cell or tissue.

BRIEF DESCRIPTION OF THE DRAWINGS:

Figure 1. Synthesis scheme of P5-SP;

Figure 2. Gel permeation chromatograph of P5-SP;

Figure 3. Structures of P5-SP, P5-BA, P5-DMA, P5-DEA and P5-TMA;

Figure 4. Cytotoxicity of PPAs in COS-7 Cells as compared with PEI and PLL;

Figure 5. Gel electrophoretic analysis of the complexation of PPAs with DNA;

Figure 6. *In vitro* transfection efficiency of PPA-DNA coacervates in HEK 293 cells;

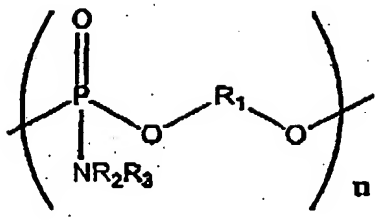
Figure 7. *In vitro* transfection efficiency of P5-SP-DNA coacervates in HEK 293 cells at different charge ratios (+/-);

Figure 8. Transfection of several cell lines using different polymeric carriers and PRE-Luciferase as a model plasmid. P5-SP-DNA coacervates are tested with different charge ratios (5 and 10 for CaCo-2 cells, HeLa cells and HUH 7 cells; 7.5 and 10 for HEK293 cells, COS-7 cells and HepG2 cells); and

Figure 9. Transfection mediated by PPA-SP/PPA-DMA mixtures at different molar ratios in COS-7 cells and HeLa cells compared with PPA-SP and PPA-DMA alone.

DETAILED DESCRIPTION OF THE INVENTION

This invention discloses a new class of cationic biodegradable polymers containing phosphoester group in the backbone and chargeable groups linked to the backbone through a phosphoramidate linkage, e.g., a P-N bond. The biodegradable polyphosphoramidate of the invention comprise the recurring monomeric units shown in the Formula I:



FORMULA I

wherein:

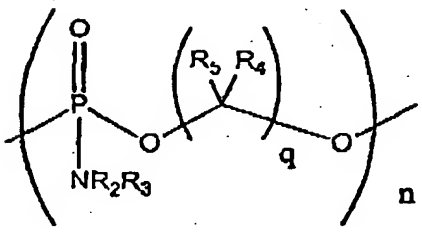
R_1 is a divalent organic moiety that is aliphatic, aromatic or heterocyclic;

R_2 and R_3 are each independently selected from the group consisting of hydrogen, alkyl, aryl, heteroaryl, heteroalicyclic, cycloalkyl, aralkyl or cycloalkylalkyl;

each non-hydrogen occurrence of R_2 and R_3 is substituted with one or more positively chargeable functional groups (e.g. primary amino group, secondary amino group, tertiary amino group and quaternary amino group, etc.); and

n is 5 to 2000.

Particularly preferred polymers according to formula I include polymers of formula II:



FORMULA II

wherein:

n, R_2 and R_3 are as defined in Formula I;

R_4 and R_5 are independently selected from the group consisting of hydrogen, alkyl, cycloalkyl, alkoxy, aryl, heteroaryl, heteroalicyclic, aralkyl, a steroid derivative; and

q is an integer from about 1 to about 5.

Preferred positively chargeable biodegradable polymers of the invention are capable of forming a complex with biologically active substances. Preferred biologically active substances include DNA, RNA, proteins, small molecule therapeutics, and the like.

Other preferred positively chargeable biodegradable polymers of the invention include polymers capable of complexing 20-60% by weight of a biologically active substance such as DNA, RNA, proteins, small molecule therapeutics, and the like.

Furthermore, preferred positively chargeable biodegradable polymers of the invention include polymers having between about 5 and about 2,000 phosphoramidate groups, more preferably between about 10 and about 1500 phosphoramidate groups, and particularly preferred are polymers having between about 20 and 1000 phosphoramidate groups. Also preferred are polymers having a molecular weight of between about 1000 and 500,000, more preferably having a molecular weight of between about 2000 and 200,000, particularly preferable are polymers having a molecular weight of between about 2000 and 100,000.

In additional preferred embodiments, positively chargeable biodegradable polymers of the invention further comprise one or more groups that facilitate intracellular or extracellular delivery of a biologically active substance. Preferred groups for facilitating intracellular delivery of a biologically active substance include a lysosomalytic agent, an amphiphilic peptide, a steroid derivative, and the like.

In preferred embodiments, the biodegradable polyphosphoramidate polymers of the invention, including polymers according to Formula I or Formula II, are biocompatible before and upon degradation.

In preferred embodiments, the biologically active substance is negatively charged. Preferred biologically active substances include anionic groups such as phosphate groups, carboxylate groups, sulfate groups and other negatively charged bio-compatible groups.

In another embodiment, the invention features a coacervate system useful for the delivery of bioactive macromolecules comprising the biodegradable polymer of Formula I.

In another embodiment, the invention features polymer conjugates comprising polymers of Formula I and bioactive ligands that could facilitate cell uptake and intracellular trafficking steps.

In another embodiment of the invention, coacervate systems useful for delivery of nucleic acids (DNA or RNA) and/or protein drugs and comprise the biodegradable polymer of Formula I or the above-described polymer conjugates are described.

In a further embodiment, the invention contemplates a process of making polymeric coacervates for delivery of protein drugs or nucleic acid.

This invention also describes a number of procedures for preparing the biodegradable polymers described above.

The biodegradable polymers could be copolymers having one or several different monomeric recurring units described in Formula I.

A lipophilic moiety, e.g. a group bearing cholesterol structural or lipid, could be conjugated to the carriers to enhance the interaction between complexes and cell membrane therefore facilitates cell uptake.

An endolysosomalytic agent, e.g. an amphiphilic peptide, could be conjugated to the carriers to enhance the endosomal escape after cell uptake step.

A nucleus localization signal could be conjugated to the carriers to facilitate the nucleus translocation.

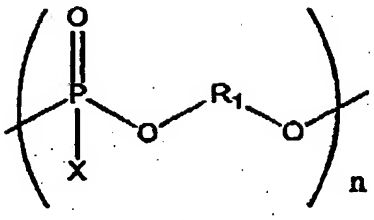
It is a discovery of the present invention that nucleic acid molecules of various chain lengths can complex with these biodegradable polymers of Formula I in aqueous conditions to form coacervates or solid microparticles ranging from submicron to microns in size. These coacervates containing nucleic acids, when appropriately targeted, can transfect cells with phagocytic activity.

According to the present invention, other molecules, especially those carry charges and have relatively higher molecular weights could also be incorporated into the complexes/coacervates.

In a further embodiment, the invention contemplates a process of making polymeric coacervates for delivery of bioactive macromolecules.

In yet another embodiment, the invention comprises articles comprising one or several different polymers with structures shown in Formula I and bioactive substances, e.g. nucleic acids and other negatively charged macromolecules for sustained release of these bioactive substances in-vivo and/or in-vitro. Additionally, the bioactive substances can be released in a controlled, sustained manner either an intracellular and extracellular manner.

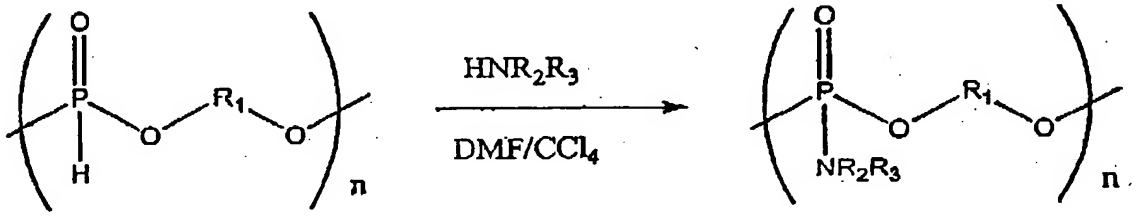
In a still further embodiment, the invention contemplates a process for preparing biodegradable polyphosphoramidates, which comprises a step of reacting a polymer shown in Formula III, wherein X is a halogen and R^1 is as defined in Formula I, with a primary or secondary amine having a general structure as R^2R^3NH, wherein R_2 and R_3 are each independently selected from the group consisting of hydrogen, alkyl, aryl, heteroaryl, heteroalicyclic, cycloalkyl, aralkyl or cycloalkylalkyl wherein each non-hydrogen occurrence of R_2 and R_3 is substituted with one or more positively chargeable functional groups (e.g. primary amino group, secondary amino group, tertiary amino group and quaternary amino group, etc.).



FORMULA III

In specific embodiments, one or more charged groups that are present in R_2 or R_3 are capable of reacting with a P-halogen bond. Preferably, such reactive positively chargeable groups are protected using standard organic chemistry protecting group techniques to prevent reaction of such groups with the P-X bond. The protected primary or secondary amine, R_2R_3NH, is then reacted with the polymer of Formula III where X is a halogen. In particularly preferred embodiments, reactive positively chargeable groups include primary or secondary amine groups which are protected using standard amine protection methodologies.

In other preferred embodiments, phosphoramidate polymers of the invention can be prepared by formation of a P-N linkage by reacting a polymer of Formula II wherein X is hydrogen with a primary or secondary amine in a polar aprotic solvent mixture such as DMF/CCl_4 to Scheme 1.



Scheme 1.

The biodegradable polymeric system described in the present invention achieves sustained and localized delivery of one or more therapeutic agents to a designated biological tissue or site in a patient. In particular, the polymeric system of the invention achieve sustained and localized delivery of one or more genes in skeletal muscles or

intradermally and achieve a higher gene transfer efficiencies than other plasmid delivery systems currently under investigation. The biodegradable polymeric carriers described in the present invention achieve gene transfer efficiencies *in vitro* and *in vivo* that are superior to other polycationic carriers currently under investigation.

The polyphosphoramidate carriers of the present invention typically offer the following advantages over other biodegradable carriers described in the literatures and patents:

Polyphosphoramidate polymers of the invention are biodegradable wherein the polymers have a cleavable backbone , either hydrolytically or enzymatically. The two most effective polymeric carriers currently available, PEI and various dendrimeric materials, are not biodegradable and their fate, *in vivo*, after administration is still unclear.

Polyphosphoramidate polymers of the invention are biocompatible before, during and after biodegradation. Biodegradation breakdown products are typically non-toxic. The polyphosphoramidate polymers of the invention are less cytotoxic than poly-L-lysine, PEI and liposome compositions *in vitro*. In a preferred embodiment, polymers of Formula I are degraded to phosphate, 1,2-propanediol and amines R^2R^3NH. By prudent selection of the side chains, the polymer potentially has minimal toxicity before and upon degradation.

Polyphosphoramidate polymers described in the present patent have higher molecule weight than most other biodegradable carriers reported in the literatures whose number average molecular weights are in the range of 3,000 to 9,000. The biodegradable polymers described here generally have number average molecular weights in the range of 10,000 to 500,000. Higher molecular weight of the polymeric carriers generally increases the binding capacity of the carriers such that the polymers of the invention typically exhibit superior uptake of DNA and protein.

The structures of polyphosphoramidate polymers are tailorable to have variable charged groups with different pKb, different charge density, molecular weight, hydrophilicity/hydrophobicity balance to optimize the transfection activity of the carriers. An endolysosomalytic agent, e.g. an amphiphilic peptide, may be conjugated to the carriers to enhance the endosomal escape after cell uptake step. A lipophilic moiety, e.g. a group bearing cholesterol structural or lipid, may be conjugated to the carriers to enhance the interaction between complexes and cell membrane therefore facilitate cell uptake. A nucleus localization signal could be conjugated to the carriers to facilitate the nucleus translocation.

Polyphosphoramidates suitable for use in the invention may be modified to comprise one or more specific ligands conjugated to the side chain or as a side chain group to enhance the cellular uptake of one or more bioactive molecules (nucleic acids and proteins) dispersed in carrier polymer and/or achieve tissue/cell specific delivery of the bioactive cargo.

Polyphosphoramidate polymers suitable for use in the methods of the invention typically posses higher molecular weights than polymeric carriers disclosed in the art such that complexes/coacervates comprising the polyphosphoramidates of the invention are more stable than other polycationic materials with lower molecular weights.

Polyphosphoramidate polymers and compositions comprising at least one bioactive molecule and a polyphosphoramidate polymer are prepared by reproducible and easily scalable procedures.

An attractive coacervate delivery system requires a delicate balance among factors such as the simplicity of preparation, cost effectiveness, nucleic acids loading level, controlled release ability, storage stability, and immunogenicity of the components. The gene delivery system described here may offer advantages compared to other particulate delivery systems, including the liposomal system. The problems of instability, low loading level, and controlled release ability are better resolved with these polymeric

systems. Compared to other synthetic polymeric systems, such as the extensively studied polylactic/polyglycolic copolymers, the mild conditions of coacervate formulation are appealing. Unlike the solvent evaporation and hot-melt techniques used to formulate synthetic polymeric coacervates, complex coacervation requires neither contact with organic solvents nor heat. It is also particularly suitable for encapsulating bio-macromolecules such as nucleic acids and proteins not only through passive solvent capturing but also by direct charge-charge interactions.

Targeting ligands can be directly bound to the surface of the coacervates. Alternatively, such ligands can be conjugated to the polymeric carriers to form molecular conjugates, which then complex with nucleic acids and/or proteins. Targeting ligands according to the present invention are any molecules, which bind to specific types of cells in the body. These may be any types of molecules for which a cellular receptor exists. Preferably the cellular receptors are expressed on specific cell types only. Examples of targeting ligands that may be used are hormones, antibodies, cell-adhesion molecules, oligosaccharides, drugs, and neurotransmitters.

The method of the present invention involves a coacervation process described in US Patent 5,972,707 (Roy, et al., 1999, Gene Delivery System) and US Patent 6,025337 (Truong, et al., 2000, Solid Microparticles for Gene Delivery). The process is optimized in this invention to best suit the complexation of nucleic acids and biodegradable carriers of Formula I.

It is a discovery of the present invention that different polymers with different charged groups, e.g. different amino groups with a wide range of acidity (pKb), could be included into one coacervate/complex system for the intracellular delivery. Such a system could offer buffering capacity similar to that of PEI.

Polyphosphoramidates suitable for use in the methods of the present invention include any and all different single pure isomers and mixtures of two or more isomers. The term isomer is intended to include diastereoisomers, enantiomers, regioisomers,

structural isomers, rotational isomers, tautomers, and the like. For compounds which contain one or more stereogenic centers, e.g., chiral compounds, the methods of the invention may be carried out with a enantiomerically enriched compound, a racemate, or a mixture of diastereomers. Preferred enantiomerically enriched compounds have an enantiomeric excess of 50% or more, more preferably the compound has an enantiomeric excess of 60%, 70%, 80%, 90%, 95%, 98%, or 99% or more.

Polyphosphoramidates suitable for use in the methods of the present invention include any and all molecular weight distribution profiles, i.e., polymers having a M_w, or M_n of between 1 and about 50, more typically a M_w, or M_n between about 1.2 and about 10. Moreover, polyphosphroamidates of the invention have a polydispersity index of between about 1 and about 5.

As also discussed above, typical subjects for administration in accordance with the invention are mammals, such as primates, especially humans.

Biodegradable polymers differ from non-biodegradable polymers in that they can be degraded during *in vivo* therapy. This generally involves breaking down the polymer into its monomeric subunits. In principle, the ultimate hydrolytic breakdown products of polymers suitable for use in the methods of the present invention should be biocompatible, non-toxic and easily excreted from a patient's body. However, the intermediate oligomeric products of the hydrolysis may have different properties. Thus, toxicology of a biodegradable polymer intended for implantation or injection, even one synthesized from apparently innocuous monomeric structures, is typically determined after one or more toxicity analyses.

The biodegradable polymer of the invention is preferably sufficiently pure to be biocompatible itself and remains biocompatible upon biodegradation. "Biocompatible" is defined to mean that the biodegradation products and/or the polymer itself are nontoxic and result in only minimal tissue irritation when instilled in the bladder or transported or otherwise localized to other tissues within a patient.

It will be appreciated that the actual preferred amounts of therapeutic agent or other component used in a given composition will vary according to the therapeutic agent being utilized including the polymer system being employed, the mode of application, the particular site of administration, etc. Optimal administration rates for a given protocol of administration can be readily ascertained by those skilled in the art using conventional dosage determination tests conducted with regard to the foregoing guidelines.

As used herein, "alkyl" is intended to include branched, straight-chain and cyclic saturated aliphatic hydrocarbon groups including alkylene, having the specified number of carbon atoms. Examples of alkyl include, but are not limited to, methyl, ethyl, n-propyl, i-propyl, n-butyl, s-butyl, t-butyl, n-pentyl, and s-pentyl. Alkyl groups typically have 1 to about 16 carbon atoms, more typically 1 to about 20 or 1 to about 12 carbon atoms. Preferred alkyl groups are C_1-C_{20} alkyl groups, more preferred are C_{1-12}-alkyl and C_{1-6}-alkyl groups. Especially preferred alkyl groups are methyl, ethyl, and propyl.

As used herein, "heteroalkyl" is intended to include branched, straight-chain and cyclic saturated aliphatic hydrocarbon groups including alkylene, having the specified number of carbon atoms and at least one heteroatom, e.g., N, O or S. Heteroalkyl groups will typically have between about 1 and about 20 carbon atoms and about 1 to about 8 heteroatoms, preferably about 1 to about 12 carbon atoms and about 1 to about 4 heteroatoms. Preferred heteroalkyl groups include the following groups. Preferred alkylthio groups include those groups having one or more thioether linkages and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alylthio groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Prefered alkylsulfinyl groups include those groups having one or more sulfoxide (SO) groups and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alkylsulfinyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Preferred alkylsulfonyl groups include those groups having one or more sulfonyl (SO_2) groups and from 1 to about 12 carbon atoms, more preferably from 1 to

about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alylsulfonyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Preferred aminoalkyl groups include those groups having one or more primary, secondary and/or tertiary amine groups, and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Aminoalkyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred.

As used herein, "heteroalkenyl" is intended to include branched, straight-chain and cyclic saturated aliphatic hydrocarbon groups including alkenylene, having the specified number of carbon atoms and at least one heteroatom, e.g., N, O or S. Heteroalkenyl groups will typically have between about 1 and about 20 carbon atoms and about 1 to about 8 heteroatoms, preferably about 1 to about 12 carbon atoms and about 1 to about 4 heteroatoms. Preferred heteroalkenyl groups include the following groups. Preferred alkylthio groups include those groups having one or more thioether linkages and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alkenylthio groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Prefered alkenylsulfinyl groups include those groups having one or more sulfoxide (SO) groups and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alkenylsulfinyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Preferred alkenylsulfonyl groups include those groups having one or more sulfonyl (SO_2) groups and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alkenylsulfonyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Preferred aminoalkenyl groups include those groups having one or more primary, secondary and/or tertiary amine groups, and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Aminoalkenyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred.

As used herein, "heteroalkynyl" is intended to include branched, straight-chain and cyclic saturated aliphatic hydrocarbon groups including alkynylene, having the specified number of carbon atoms and at least one heteroatom, e.g., N, O or S. Heteroalkynyl groups will typically have between about 1 and about 20 carbon atoms and about 1 to about 8 heteroatoms, preferably about 1 to about 12 carbon atoms and about 1 to about 4 heteroatoms. Preferred heteroalkynyl groups include the following groups. Preferred alkynylthio groups include those groups having one or more thioether linkages and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alkynylthio groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Preferd alkynylsulfinyl groups include those groups having one or more sulfoxide (SO) groups and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alkynylsulfinyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Preferred alkynylsulfonyl groups include those groups having one or more sulfonyl (SO_2) groups and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Alkynylsulfonyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred. Preferred aminoalkynyl groups include those groups having one or more primary, secondary and/or tertiary amine groups, and from 1 to about 12 carbon atoms, more preferably from 1 to about 8 carbon atoms, and still more preferably from 1 to about 6 carbon atoms. Aminoalkynyl groups having 1, 2, 3, or 4 carbon atoms are particularly preferred.

As used herein, "cycloalkyl" is intended to include saturated ring groups, having the specified number of carbon atoms, such as cyclopropyl, cyclobutyl, cyclopentyl, or cyclohexyl. Cycloalkyl groups typically will have 3 to about 8 ring members.

In the term "(C_{3-6} cycloalkyl)C_{1-4} alkyl", as defined above, the point of attachment is on the alkyl group. This term encompasses, but is not limited to, cyclopropylmethyl, cyclohexylmethyl, cyclohexylmethyl.

As used here, "alkenyl" is intended to include hydrocarbon chains of straight, cyclic or branched configuration, including alkenylene, and one or more unsaturated carbon-carbon bonds which may occur in any stable point along the chain, such as ethenyl and propenyl. Alkenyl groups typically will have 2 to about 12 carbon atoms, more typically 2 to about 12 carbon atoms.

As used herein, "alkynyl" is intended to include hydrocarbon chains of straight, cyclic or branched configuration, including alkynylene, and one or more triple carbon-carbon bonds which may occur in any stable point along the chain, such as ethynyl and propynyl. Alkynyl groups typically will have 2 to about 20 carbon atoms, more typically 2 to about 12 carbon atoms.

As used herein, "haloalkyl" is intended to include both branched and straight-chain saturated aliphatic hydrocarbon groups having the specified number of carbon atoms, substituted with 1 or more halogen (for example $-C_vF_w$ where $v = 1$ to 3 and $w = 1$ to $(2v+1)$. Examples of haloalkyl include, but are not limited to, trifluoromethyl, trichloromethyl, pentafluoroethyl, and pentachloroethyl. Typical haloalkyl groups will have 1 to about 16 carbon atoms, more typically 1 to about 12 carbon atoms.

As used herein, "alkoxy" represents an alkyl group as defined above with the indicated number of carbon atoms attached through an oxygen bridge. Examples of alkoxy include, but are not limited to, methoxy, ethoxy, n-propoxy, i-propoxy, n-butoxy, 2-butoxy, t-butoxy, n-pentoxy, 2-pentoxy, 3- pentoxy, isopentoxy, neopentoxy, n-hexoxy, 2-hexoxy, 3-hexoxy, and 3-methylpentoxy. Alkoxy groups typically have 1 to about 16 carbon atoms, more typically 1 to about 12 carbon atoms.

"Prodrugs" are intended to include any covalently bonded carriers which release the active parent drug according to formula I *in vivo* when such prodrug is administered to a mammalian subject. Prodrugs of a compound are prepared by modifying functional

groups present in the drug compound in such a way that the modifications are cleaved, either in routine manipulation or *in vivo*, to the parent compound.

Combinations of substituents and/or variables are permissible only if such combinations result in stable compounds. A stable compound or stable structure is meant to imply a compound that is sufficiently robust to survive isolation to a useful degree of purity from a reaction mixture, and formulation into an effective therapeutic agent.

As used herein, the term "aliphatic" refers to a linear, branched, cyclic alkane, alkene, or alkyne. Preferred aliphatic groups in the poly(phosphoester-co-amide) polymer of the invention are linear or branched and have from 1 to 20 carbon atoms.

As used herein, the term "aryl" refers to an unsaturated cyclic carbon compound with $4n+2$ electrons where n is a non-negative integer, about 5-18 aromatic ring atoms and about 1 to about 3 aromatic rings.

As used herein, the term "heterocyclic" refers to a saturated or unsaturated ring compound having one or more atoms other than carbon in the ring, for example, nitrogen, oxygen or sulfur.

The polymers of the invention are usually characterized by a release rate of the therapeutic agent in vivo that is controlled at least in part as a function of hydrolysis of the phosphoester bond of the polymer during biodegradation. Additionally, the therapeutic agent to be released may be conjugated to the sidechain of the phosphramidate repeat unit to form a pendant drug delivery system. Further, other factors are also important.

The life of a biodegradable polymer in vivo also depends upon its molecular weight, crystallinity, biostability, and the degree of cross-linking. In general, the greater the molecular weight, the higher the degree of crystallinity, and the greater the biostability, the slower biodegradation will be.

The therapeutic agent of the invention can vary widely with the purpose for the composition. The agnet(s) may be described as a single entity or a combination of entities. The delivery system is designed to be used with therapeutic agents having high water-solubility as well as with those having low water-solubility to produce a delivery system that has controlled release rates. The terms "therapeutic agent" and "biologically active substance" include without limitation, medicaments; vitamins; mineral supplements; substances used for the treatment, prevention, diagnosis, cure or mitigation of disease or illness; or substances which affect the structure or function of the body; or pro-drugs, which become biologically active or more active after they have been placed in a predetermined physiological environment.

Non-limiting examples of useful therapeutic agents and biologically active substances include the following expanded therapeutic categories: anabolic agents, antacids, anti-asthmatic agents, anti-cholesterolemic and anti-lipid agents, anti-coagulants, anti-convulsants, anti-diarrheals, anti-emetics, anti-infective agents, anti-inflammatory agents, anti-manic agents, anti-nauseants, anti-neoplastic agents, anti-obesity agents, anti-pyretic and analgesic agents, anti-spasmodic agents, anti-thrombotic agents, anti-uricemic agents, anti-anginal agents, antihistamines, anti-tussives, appetite suppressants, biologicals, cerebral dilators, coronary dilators, decongestants, diuretics, diagnostic agents, erythropoietic agents, expectorants, gastrointestinal sedatives, hyperglycemic agents, hypnotics, hypoglycemic agents, ion exchange resins, laxatives, mineral supplements, mucolytic agents, neuromuscular drugs, peripheral vasodilators, psychotropics, sedatives, stimulants, thyroid and anti-thyroid agents, uterine relaxants, vitamins, antigenic materials, and prodrugs.

Specific examples of useful therapeutic agents and biologically active substances, i.e., bioactive molecules, from the above categories include: (a) anti-neoplastics such as androgen inhibitors, antimetabolites, cytotoxic agents, immunomodulators; (b) anti-tussives such as dextromethorphan, dextromethorphan hydrobromide, noscapine, carbetapentane citrate, and chlophedianol hydrochloride; (c) antihistamines such as

chlorpheniramine maleate, phenindamine tartrate, pyrilamine malcate, doxylamine succinate, and phenyltoloxamine citrate; (d) decongestants such as phenylephrine hydrochloride, phenylpropanolamine hydrochloride, pseudoephedrine hydrochloride, and ephedrine; (e) various alkaloids such as codeine phosphate, codeine sulfate and morphine; (f) mineral supplements such as potassium chloride, zinc chloride, calcium carbonates, magnesium oxide, and other alkali metal and alkaline earth metal salts; (g) ion exchange resins such as cholestryramine; (h) anti-arrhythmics such as N-acetylprocainamide; (i) antipyretics and analgesics such as acetaminophen, aspirin and ibuprofen; (j) appetite suppressants such as phenyl-propanolamine hydrochloride or caffeine; (k) expectorants such as guaifenesin; (l) antacids such as aluminum hydroxide and magnesium hydroxide; (m) biologicals such as peptides, polypeptides, proteins and amino acids, hormones, interferons or cytokines and other bioactive peptidic compounds, such as hGH, tPA, calcitonin, ANF, EPO and insulin; (n) anti-infective agents such as anti-fungals, anti-virals, antiseptics and antibiotics; and (o) antigenic materials, partricularly those useful in vaccine applications.

Preferably, the therapeutic agent or biologically active substance is selected from the group consisting of DNA, polysaccharides, growth factors, hormones, anti-angiogenesis factors, interferons or cytokines, and pro-drugs. In a particularly preferred embodiment, the therapeutic agent is a DNA vaccine comprising a DNA sequence encoding an antigen, a DNA sequence encoding a cytokine or a mixture of DNA sequences encoding an antigen and a cytokine.

The therapeutic agents are used in amounts that are therapeutically effective. While the effective amount of a therapeutic agent will depend on the particular material being used, amounts of the therapeutic agent from about 1% to about 65% have been easily incorporated into the present delivery systems while achieving controlled release. Lesser amounts may be used to achieve efficacious levels of treatment for certain therapeutic agents.

In addition, the polymer composition of the invention can also comprise polymer blends of the polymer of the invention with other biocompatible polymers, so long as they do not interfere undesirably with the biodegradable characteristics of the composition. Blends of the polymer of the invention with such other polymers may offer even greater flexibility in designing the precise release profile desired for targeted drug delivery or the precise rate of biodegradability desired for structural implants such as for orthopedic applications. Examples of such additional biocompatible polymers include other polycarbonates; polyesters; polyorthoesters; polyamides; polyurethanes; poly(iminocarbonates); and polyanhydrides.

As a drug delivery device, the polymer compositions of the invention provide a polymeric matrix capable of sequestering a biologically active substance and provide predictable, controlled delivery of the substance. The polymeric matrix then degrades to non-toxic residues.

It will be understood, however, that the specific dose level for any particular patient will depend upon a variety of factors including the activity of the specific compound employed, the age, body weight, general health, sex, diet, time of administration, route of administration, and rate of excretion, drug combination (i.e., other drugs being administered to the patient), the severity of the particular disease undergoing therapy, and other factors, including the judgment of the prescribing medical practitioner.

A positively chargeable biodegradable polymer composition of the invention also may be packaged together with instructions (i.e. written, such as a written sheet) for treatment of a disorder as disclosed herein, e.g. instruction for treatment of a subject that is susceptible to or suffering from a disease or disorder which may be treated by administration of a bioactive molecule, e.g., therapeutic agent, dispersed in the positively chargeable biodegradable polymer composition.

A positively chargeable biodegradable polymer composition of the invention be administered parenterally, preferably in a sterile non-toxic, pyrogen-free medium. The drug, depending on the vehicle and concentration used, can either be suspended or dissolved in the vehicle. Advantageously, adjuvants such as local anesthetics, preservatives and buffering agents can be dissolved in the vehicle. The term parenteral as used herein includes injections and the like, such as subcutaneous, intradermal, intravascular (e.g., intravenous), intramuscular, intrasternal, spinal, intrathecal, and like injection or infusion techniques, with subcutaneous, intramuscular and intravascular injections or infusions being preferred.

A positively chargeable biodegradable polymer composition of the invention also may be packaged together with instructions (i.e. written, such as a written sheet) for treatment of a disorder as disclosed herein, e.g. instruction for treatment of a subject that is susceptible to or suffering from inflammation, cellular injury disorders, or immune system disorders.

The following examples are illustrative of the invention. All documents mentioned herein are incorporated herein by reference.

EXAMPLES:

The following examples are offered by way of illustration and are not intended to limit the invention in any manner.

Example 1. Synthesis and characterization of polyphosphoramidates

1.1 Synthesis of P5-SP (structure shown in Figure 3)

The synthetic scheme of P5-SP is shown in Figure 1. Poly(4-methyl-2-oxo-2-hydro-1,3,2-dioxaphospholane) is synthesized according to the procedure described in the literature (*Biela T, Penczek S, and Slomkowski S. 1982. Racemic and optimal active poly(4-methyl-2-oxo-2-hydro-1,3,2-dioxaphospholane): Synthesis and oxidation to the polyacids. Makromol. Chem. Rapid Commun. 3: 667-671*). Briefly, 2-hydroxy-4-methyl-1,3,2-dioxaphospholane (58g, 0.475mol) [freshly prepared according to Lucas' method (*Lucas HJ, Mitchell FW, Jr., and Scully CN. 1950. Cyclic phosphites of some aliphatic glycols. J. Am. Chem. Soc. 72: 5491-5497*) is polymerized in 200 ml of freshly dried $CHCl_3$ at room temperature for 48 hours. Polymerization is initiated with triisobutylaluminum (1wt%, 4ml of 15% solution in heptane). The polymer is obtained by precipitation into anhydrous benzene. This polymer become insoluble in chloroform after precipitation, but it is soluble in anhydrous DMF.

Poly(4-methyl-2-oxo-2-hydro-1,3,2-dioxaphospholane) (1.094 g, 8.9 mmol P-H groups) is dissolved in anhydrous DMF (10 ml). To this solution is added 5 ml of anhydrous CCl_4 and N^1,N^8-bis(trifluroacetyl)spermidine trifluroacetate (10.8 mmol, 4.9 g) in 10 ml of DMF using a syringe, followed by addition of 5 ml of anhydrous triethylamine under ice-water bath. The reaction is performed at 0 C for 30 minutes then at room temperature overnight. The resulted solution is concentrated and product is obtained by precipitating in water followed by drying under vacuum.

The resulted polymer is suspended in 30 ml of concentrated ammonia solution and the mixture is stirred at 60 C for 16 hours. The solution is concentrated and dialyzed against water overnight using a dialysis tubing with a MWCO of 7,500. P5-SP is

obtained after lyophilizing the dialyzed solution. The structure of P5-SP is confirmed by proton-NMR: δ (ppm): 1.35-1.4 (d, 3H), 1.5-1.7 (4H), 1.75-1.95 (2H), 2.65-2.95 (4H), 3.0-3.2 (4H), 3.75-4.15 (m, 2H), 4.35-4.65 (d, b, 1H). Figure 2 shows a typical chromatograph by gel permeation chromatography analysis of P5-SP. It is indicated that P5-SP synthesized has a weight average molecular weight of 4.58×10^4, and number average molecular weight of 3.14×10^4 (Polydispersity=1.46).

1.2 Synthesis of P5-DMA (structure shown in Figure 3)

To a solution of poly(4-methyl-2-oxo-2-hydro-1,3,2-dioxaphospholane) in anhydrous DMF cooled with ice-water bath, was added 5mL of anhydrous CCl_4 and N,N-dimethylethylenediamine (20% excess to P-H) solution in, followed by addition of large excess of triethylamine. The reaction was performed at 0 C for 30 minutes and at room temperature overnight. P5-DMA was obtained by dialysis against water using a dialysis member with a MWCO of 2,000.

To the solution of P5-DMA (100 mg) in 5ml of methanol was added CH_3I (1 ml) and the mixture was allowed to stay at room temperature overnight. The resulted solution was concentrated and precipitated into ether. P5-TMA was obtained as yellowish power. The number average molecular weight of P5-TMA was 2.62×10^4 as measured by GPC/LS/RI method.

P5-BA, P5-DEA and P5-TMA (Structures are shown in Figure 3) are synthesized according to a similar procedure.

Example 2. Assay for the cytotoxicity of polyphosphoramidates (PPAs)

Cytotoxicity of polyphosphoramidates (P5-SP, P5-BA, P5-DMA, P5-DEA and P5-TMA) in comparison with other potential gene carriers [poly-L-lysine (PLL) and polyethylenimine (PEI)] is evaluated using the WST-1 dye reduction assay. COS-7 cells are seeded in a 96 well plate 24 hours before the assay at the density of 5×10^4 cells/well. The cells are incubated for 4 hours with 100 µl of DMEM medium complemented with 10% fetal bovine serum (FBS) containing various PPAs, or PLL or PEI at different

concentrations ranging from 0 to 500 μg/ml. The medium in each well is replaced with 100 μl of fresh complete medium and cells are cultured for an additional 20 hrs. Ten microliters of WST-1 reagent (Roche Molecular Biochemicals) is added to each well and allowed reacting for 4 hrs at 37 °C. The absorbance of the supernatant at 450 nm (use 655 nm as a reference wavelength) is measured using a microplate reader (Model 550, Bio-Rad Lab. Hercules, CA).

The assay results (Figure 4) indicate that polyphosphoramidates exhibit lower cytotoxicity in culture than widely used polycationic carrier, PLL and PEI. The LD_{50} of PEI in this assay is 20 μg/ml, LD_{50} of PLL is 42 μg/ml, LD_{50} of P5-SP is 85 μg/ml, LD_{50} of P5-BA is 300 μg/ml, LD_{50} of DMA or DEA or TMA is well beyond 500 μg/ml. It is clear that PPAs have lower cytotoxicity than PLL and PEI. PPAs with tertiary amino group and quaternary amino groups have the lowest cytotoxicity in this assay.

Example 3. Gel retardation assay for the DNA binding capacity of PPAs

The formation of PPA-DNA coacervates is examined by their electrophoretic mobility on an agarose gel at various charge ratios of PPAs to plasmid DNA (Figure 5). No migration of the plasmid DNA occurred at charge ratio larger than 1.0 (P5-DMA, P5-DEA and P5-TMA) or 1.5 (P5-BA) or 2.0 (P5-SP). This lack of migration is due to neutralization of the nucleic acid by PPAs, suggesting the polycationic nature of PPAs. PPAs with tertiary amino groups and quternary amino groups appear to have higher DNA binding capacity at the same charge ratio.

Example 4. Preparation of PPA-DNA coacervates and coacervates with chloroquine sulfate

PPA is dissolved in saline at a concentration of 2-10 mg/ml. To this solution is added plasmid DNA dissolved in saline to yield desired N/P ratios, followed by brief vortexing, and the mixture is allowed to stand at room temperature for 30 minutes. The coacervates prepared according to this procedure are used directly for transfection study unless stated otherwise. The efficiency of complexation of DNA is close to 100% when the N/P ratio is over 1.0 as revealed by gel electrophoretic mobility analysis.

Chloroquine sulfate (CQ) has been widely proven to be an effective reagent to disrupt lysosomes and enhance the transfection efficiency in many polycationic gene delivery systems. CQ is co-encapsulated into the coacervates simply by incorporating CQ into the PPA solution and then forming coacervates according to the same procedure. The CQ incorporated coacervates are used for *in vitro* transfection without further purification since the total amount of CQ added is still within the non-toxic concentration range.

Example 5. Transfection efficiency of PCEP-DNA complex in different cell lines

In vitro transfection of HEK 293 cells with PPA-DNA coacervates is evaluated using luciferase as a marker gene. Cells are seeded 24 hours prior to transfection into a 24-well plate (Becton-Dickinson, Lincoln Park, NJ) at a density of 8×10^4 per well with 1 ml of complete medium (DMEM containing 10% FBS, supplemented with 2 mM L-glutamate, 50 units/ml penicillin and 50 μg/ml streptomycin). At the time of transfection, the medium in each well is replaced with 1 ml of serum free DMEM. PPA-DNA coacervates or PEI-DNA complexes or PLL-DNA complexes or Transfast™-DNA complexes are incubated with the cells for 3 hours at 37°C. The medium is replaced with 1 ml of fresh complete medium and cells are further incubated for 48 hours. All the transfection tests are performed in triplicate. After the incubation, cells are permeabilized with 200 μl of cell lysis buffer (Promega Co., Madison, WI). The luciferase activity in cell extracts is measured using a luciferase assay kit (Promega Co., Madison, WI) on a luminometer (Lumat9605, EG&G Wallac). The light units (LU) are normalized against protein concentration in the cell extracts, which is measured using BCA protein assay kit (Pierce, Rockford, IL).

Figure 6 shows the transfection efficiency of PPA-DNA coacervates prepared from five different PPAs with 100 μg/ml of CQ or without CQ, comparing with PEI, PLL and Transfast as gene carriers. Coacervates prepared with P5-SP in the presence of CQ result in the highest transfection efficiency, similar to the level obtained by Transfast-DNA complexes and PEI-DNA complexes. Other PPAs only show moderate transfection activity. It is also evident that CQ can enhance the transfection efficiency for about 4

times at a concentration of 40 μg/ml of CQ, transfection efficiency increases with dose and peaks at a dose of 80 μg/ml of CQ (data not shown). The following experiments are performed with 100 μg/ml of CQ incorporated in the coacervates.

As the gel electrophoresis analysis shows, at a +/- charge ratio of 1.0 (P5-DMA, P5-DEA and P5-TMA) or 1.5 (P5-BA) or 2.0 (P5-SP) and above, all the plasmid DNA added to the preparation mixture is complexed with PPAs. Coacervates prepared at different charge ratios are also examined for their abilities to transfect HEK293 cells (Figure 7). Although complete DNA incorporation occurs at charge ratio of 2.0 and above for P5-SP, the highest level of gene transfection is observed when the coacervates are synthesized at the +/- charge ratios between 7.5 and above. Transfection efficiency slightly decreases when the charge ratio is 12.5 and above.

The transfection efficiency is measured against five other cell lines using PPA-DNA coacervates containing pRE-Luciferase plasmid (Figures 8). Like in HEK293 cells, the highest level of luciferase expression in CaCo-2 cells, HeLa cells, HuH-7 cells, COS-7 cells and HepG2 cells is also found to be at a +/- ratio between 5 and 10. The transfection efficiency in CaCO-2 cells, HeLa cells or HuH 7 cells is about 100 to 200 times higher than PLL mediated transfection, and 10 to 50 times lower than that obtained with PEI-DNA complexes. Transfection efficiency in COS-7 cells or HepG2 cells is about 100 to 300 times higher than PLL mediated transfection and 2 folds lower than that obtained with PEI-DNA complexes.

Example 6. Gene transfection mediated by PPA mixtures

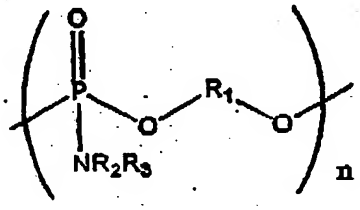
Complexes comprising plasmid DNA and PPA mixture were prepared according to a similar procedure as described in Example 4, except that PPA-SP and PPA-DMA were pre-mixed at different ratios before complexation with plasmid DNA. DNA-polymer complexes were formed by adding 50 μl of polymer solution containing varying amounts of polymer to 50 μl of vortexing pRE-luciferase (60 μg/ml, in 0.9% NaCl, pH 7.4) and vortexed for 15-30s. Complexes were allowed to form for 30 min at room temperature. The complexes were used for transfection study without further purification.

This is based on the hypothesis that complexes containing various types of amino groups would increase the buffering capacity, thus improve the intracellular delivery of the DNA to cytosol and nucleus. Transfection of COS-7 cells using PPA-SP (containing primary amino group), PPA-DMA (containing tertiary amino group) or PPA-SP/PPA-DMA mixture showed that PPA-SP/PPA-DMA mixture mediated significantly higher levels of gene expression than either polymer alone (Figure 9, structures see Figure 3). Transfection was performed with 3 μg DNA per well. The charge ratio of total positive charges in PPA to negative charges in DNA was maintained at 9. Under optimal condition (at a PPA-SP/PPA-DMA molar ratio of 4 to 9), transfection efficiency achieved by PPA-SP/PPA-DMA mixture was 20 and 160 times higher than PPA-SP and PPA-DMA mediated transfection, respectively.

This method of introducing polymeric carriers with different charged groups into the same complexes represents a simple yet effective approach in developing polymeric gene carriers and understanding the mechanisms of polymer mediated gene transfer.

What is claimed is:

1. A water soluble and positively charged biodegradable polyphosphoramidate that is capable of forming a complex with negatively charged bioactive macromolecules in aqueous solutions and comprises the recurring monomeric unit shown in Formula I,



FORMULA I

wherein

R_1 is a divalent aliphatic organic moiety;

R_2 and R_3 are each independently selected from the group consisting of hydrogen, alkyl, or heteroalicyclic groups;

each non-hydrogen occurrence of R_2 and R_3 is substituted with one or more positively charged groups; and

n is from 20 to 2,000.

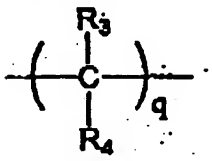
2. A positively charged biodegradable polyphosphoramidate of claim 1, wherein the biodegradable polyphosphoramidate has between about 20 and about 2,000 phosphoramidate groups.

3. A positively charged biodegradable polyphosphoramidate of claim 1, wherein non-hydrogen occurrences R_2 and R_3 are substituted with one or more charged groups selected from the group consisting of primary amine, secondary amine, tertiary amine, quaternary amine or imidazoyl.

4. A positively charged biodegradable polyphosphoramidate of claim 1, wherein one or more of R_1, R_2 or R_3 is substituted with one or more groups capable of facilitating intracellular delivery of a negatively charged bioactive macromolecules, selected from the group consisting of lysosomalytic agent, an amphiphilic peptide, or a steroid derivative.

5. A positively charged biodegradable polyphosphoramidate of claim 4, wherein the group capable of facilitating intracellular delivery of negatively charged bioactive macromolecules is a cholesteryl group.

6. A positively charged biodegradable polyphosphoramidate of claim 1, wherein R_1 is defined in Formula II,



FORMULA II

wherein

each occurrence of R_3 and R_4 are independently selected from the group consisting of hydrogen or alkyl group; and

q is 2 to 4.

7. A positively charged biodegradable polyphosphoramidate composition formed by complexation in aqueous solutions comprising:

(a) at least one negatively charged bioactive macromolecule; and

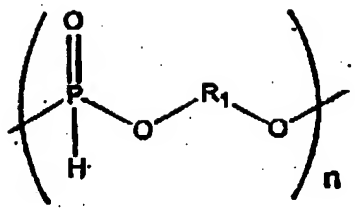
(b) a water soluble and positively charged biodegradable polyphosphoramidate of claim 1.

8. A positively charged biodegradable polyphosphoramidate composition of claim 7, wherein the negatively charged bioactive macromolecules are selected from the group consisting of DNA, RNA, proteins, and polysaccharides.

9. A positively charged biodegradable polyphosphoramidate composition of any one of claims 7 and 8, wherein the biodegradable polyphosphoramidate is capable of complexing 20-60% by weight of the negatively charged biomacromolecules.

10. A method of preparing a water soluble and positively chargeable biodegradable polyphosphoramidate of Formula I, comprising the steps of:

(a). reacting a precursor polymer with recurring unit shown in Formula III,



FORMULA III

wherein

R_1 is a divalent aliphatic organic moiety;

with a primary or secondary amine having a structure of HNR_2R_3, wherein each occurrence of R_2 and R_3 are selected from the group consisting of hydrogen or positively charged alkyl or heteroalicyclic containing protected primary amine, protected secondary amine, tertiary amine, and quaternary amine; followed by

(b). deprotecting the protected amino groups, if applicable.

11. A method of preparing a positively charged biodegradable polyphosphoramidate of claim 10, wherein the biodegradable polyphosphoramidate has between about 20 and about 200 phosphoramidate groups.

12. A method of preparing a positively charged biodegradable polyphosphoramidate composition of claim 7, comprising the steps of:

mixing an aqueous solution of the positively charged biodegradable polymer of Formula I with concentrations ranging from 1 μg/ml to 500 μg/ml,

with an aqueous solution of one or more biological active macromolecules, which is able to complex with polymer of Formula I.

13. A method of preparing a positively charged biodegradable polyphosphoramidate composition of claim 12, wherein the negatively charged or bioactive macromolecules are selected from the group consisting of DNA, RNA, proteins, and polysaccharides.

14. A method of preparing a positively charged biodegradable polyphosphoramidate composition of claim 12 or 13, wherein the biodegradable

polyphosphoramidate is capable of complexing 20-60% by weight of the negatively charged bioactive macromolecules.

15. A method of preparing a positively charged biodegradable polyphosphoramidate composition of claim 12 or 13, wherein the biodegradable polyphosphoramidate has between about 20 and about 200 phosphoramidate groups.

16. A method for the controlled release of a bioactive macromolecule comprising the steps of:

providing a positively charged biodegradable polyphosphoramidate composition of claim 7, and

contacting the composition in vivo or in vitro with a biological fluid, cell or tissue under conditions conducive to the delivery of at least a portion of the biologically active substance to the biological fluid, cell or tissue so that the biologically active substance is released in a controlled manner.

17. A method of claim 16, wherein the bioactive macromolecule is released in-vivo.

18. A method of claim 16, wherein the bioactive macromolecule is released in-vitro.

19. A method of claim 16, wherein the bioactive macromolecule is released extracellularly.

20. A method of claim 16, wherein the bioactive macromolecule is released intracellularly.

21. A method of claim 16, wherein the bioactive macromolecule(s) are selected from the group consisting of DNA, RNA, proteins, and polysaccharides.

22. A method of claim 16, wherein the biodegradable polymer is capable of complexing 20-60% by weight of the negatively charged bioactive macromolecule.

23. A method of claim 16, wherein the biodegradable polymer has between about 20 and about 200 phosphate groups.

24. A method of claim 16, wherein the bioactive macromolecule is a growth factor.

25. A method of claim 16, wherein the bioactive macromolecule is selected from the group consisting of DNA sequences, genes, gene fragments, DNA encoding vaccines, therapeutic agents, cytokines, immunoadjuvants, cancer therapeutic agents, proteins, and combinations thereof.

26. A method of claim 25, wherein the DNA sequence, gene or gene fragment is administered in connection with gene therapy.

27. A method of any one of claims 17 through 26 wherein the positively charged biodegradable polyphosphoramidate composition, including complexes or nanoparticles is delivered in vivo.

FIGURES:

Figure 1

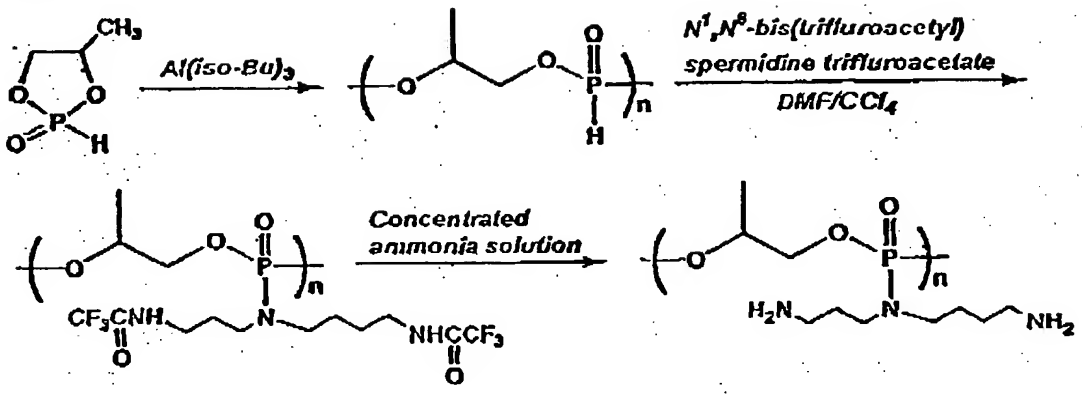


Figure 2

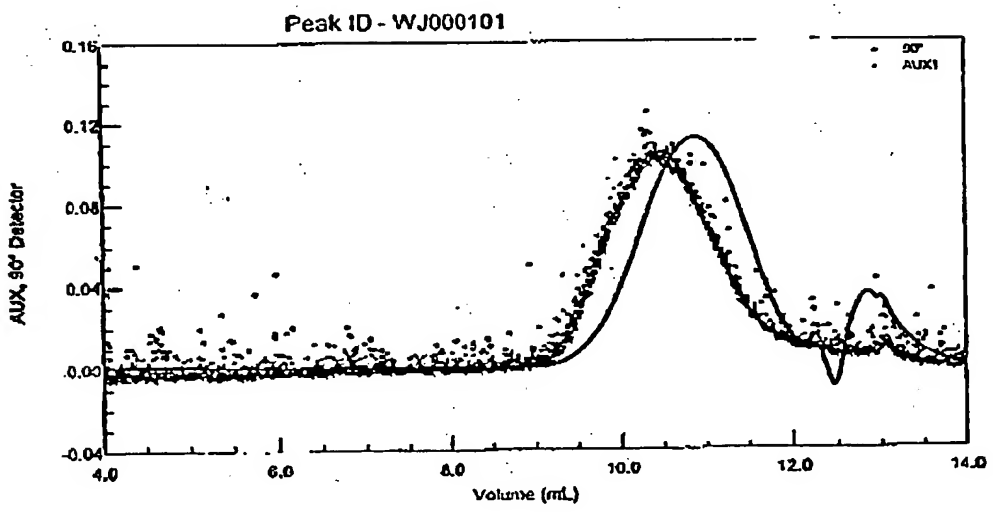


Figure 3.

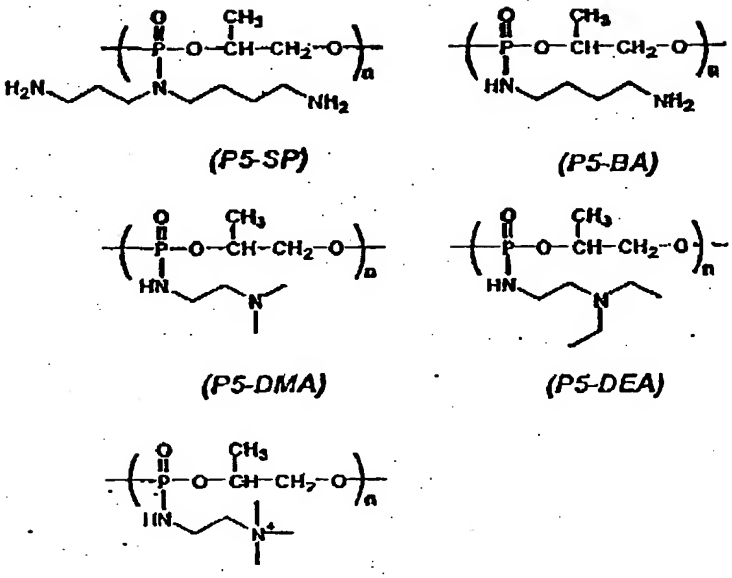


Figure 4.

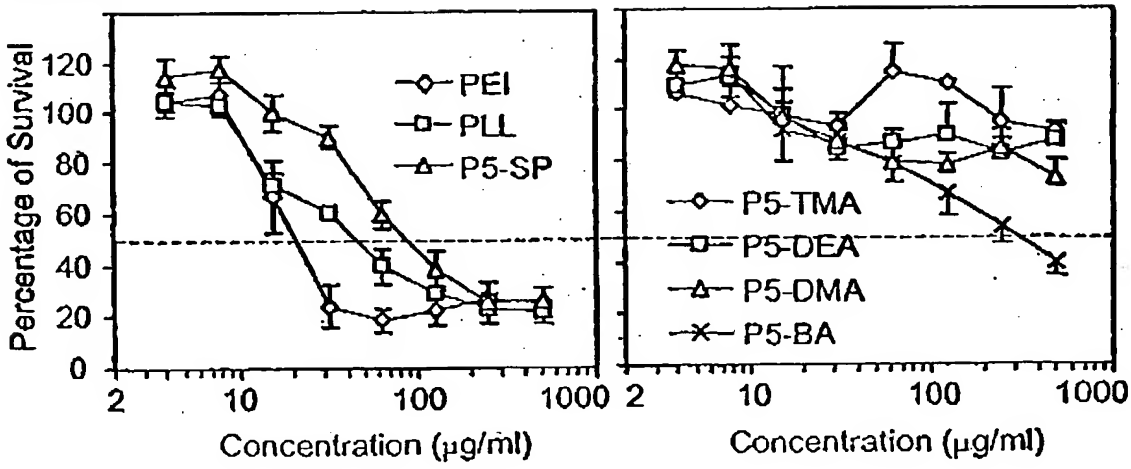


Figure 5.

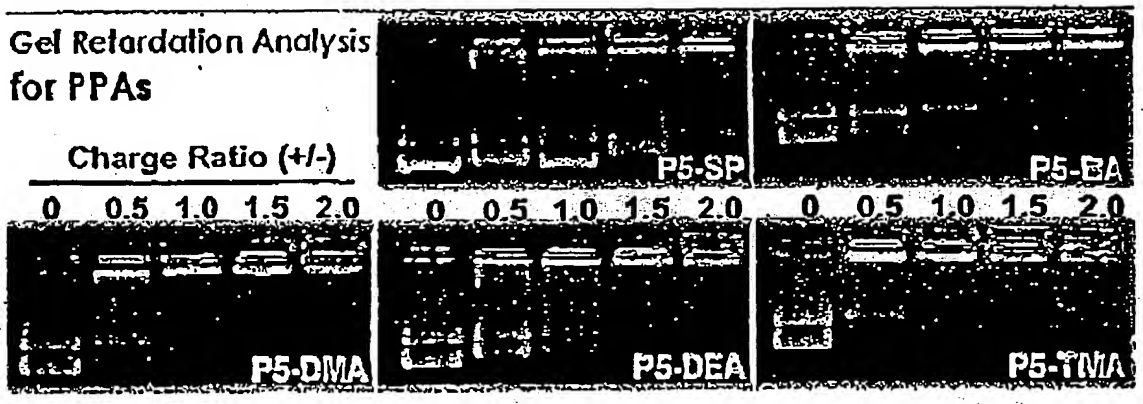


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Figure 6.

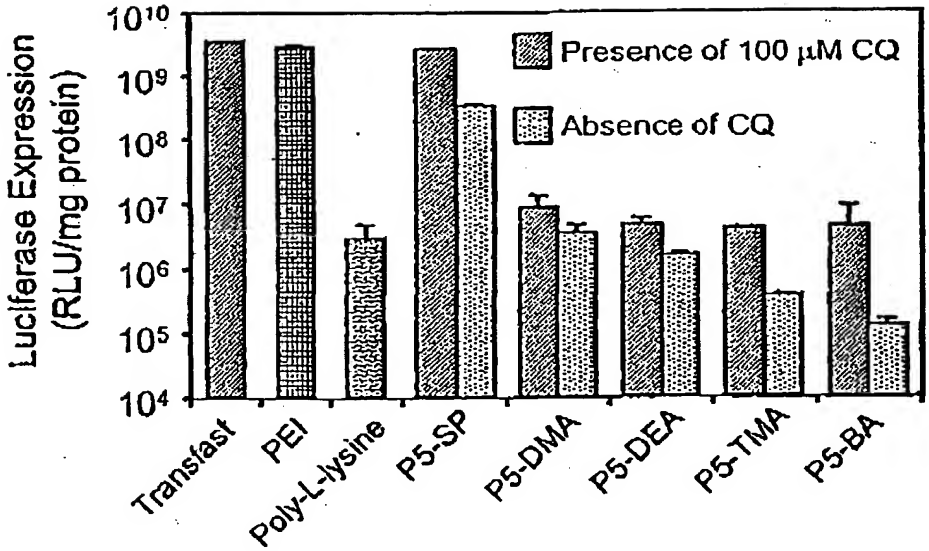
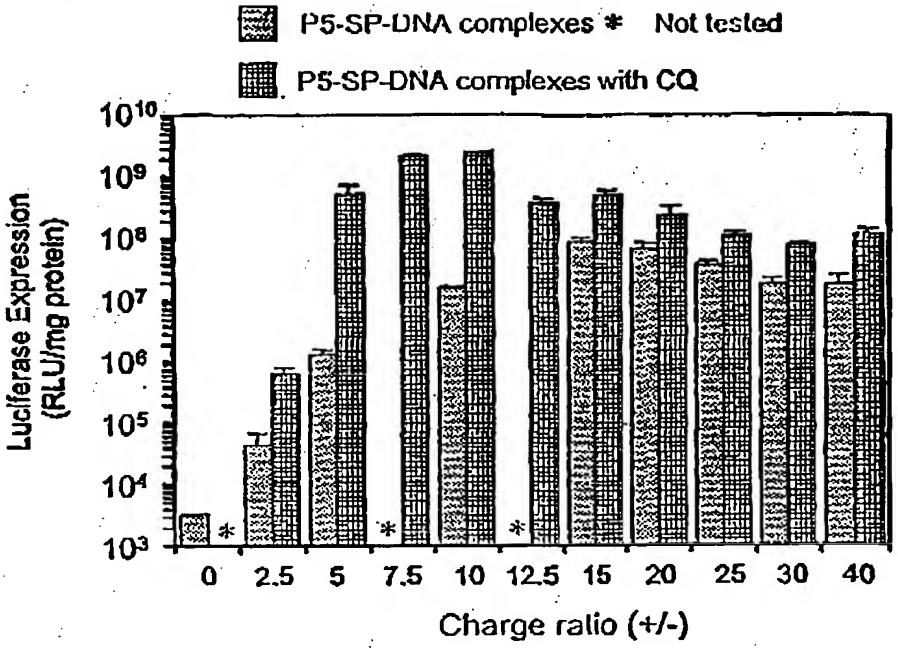


Figure 7.



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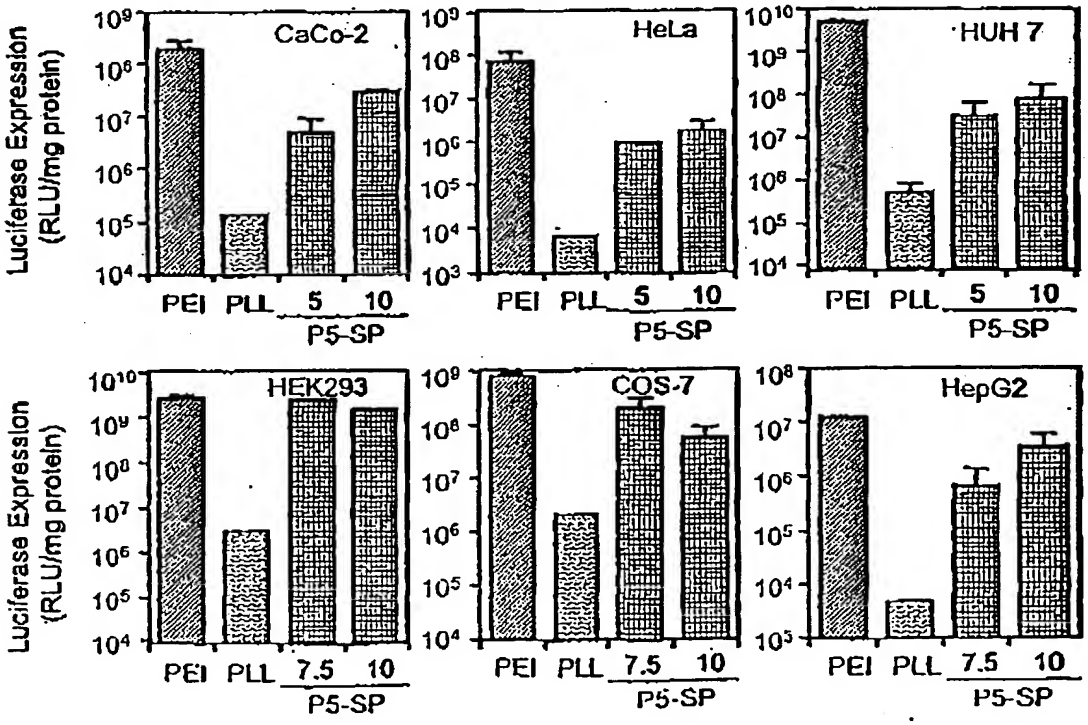
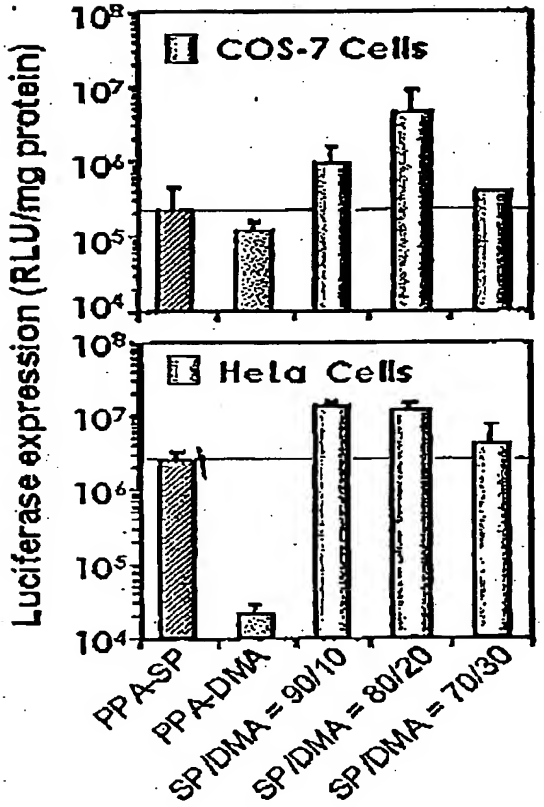


Figure 9


COS-7 Cells
Hela Cells
Luciferase expression (RLU/mg protein)
10^8
10^7
10^6
10^5
10^4
PPA-SP
PPA-DMA
SP/DMA = 90/10
SP/DMA = 80/20
SP/DMA = 70/30

Extra Set of Drawings

FIGURES:

Figure 1

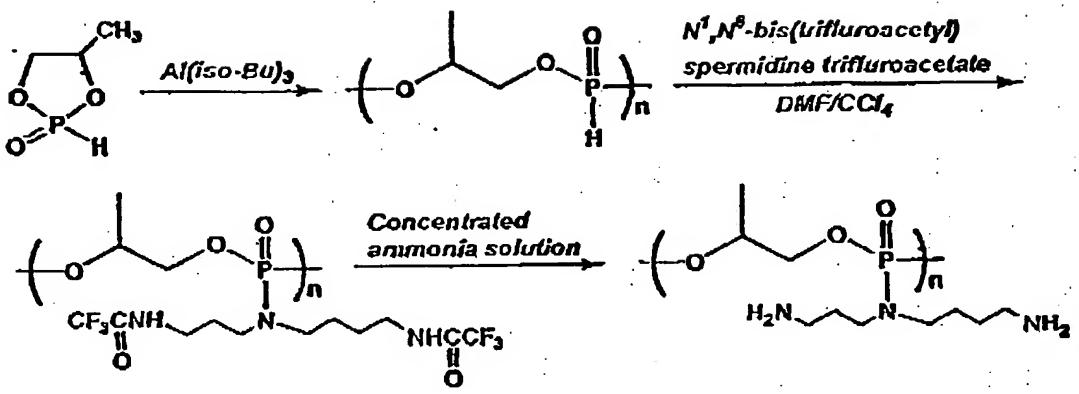


Figure 2

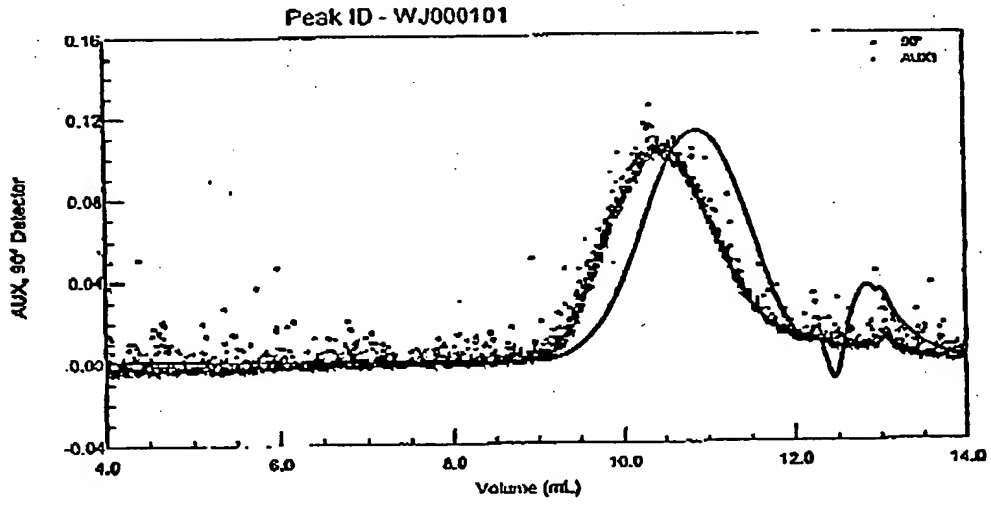


Figure 3.

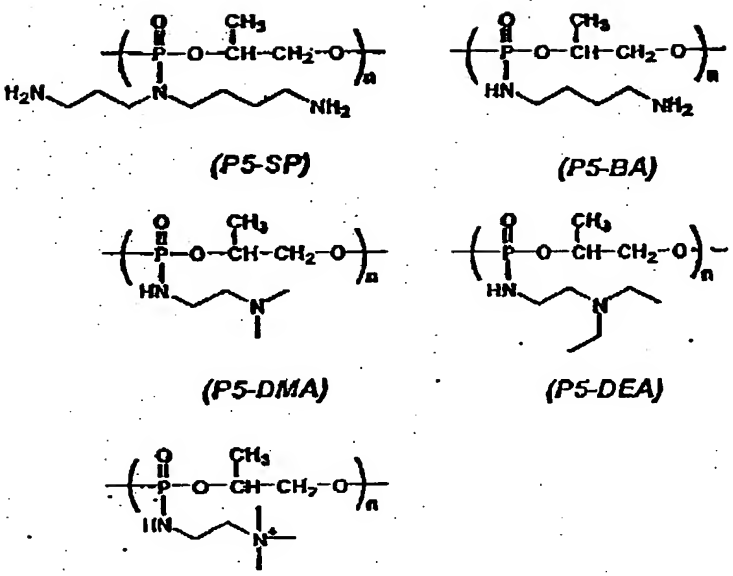


Figure 4.

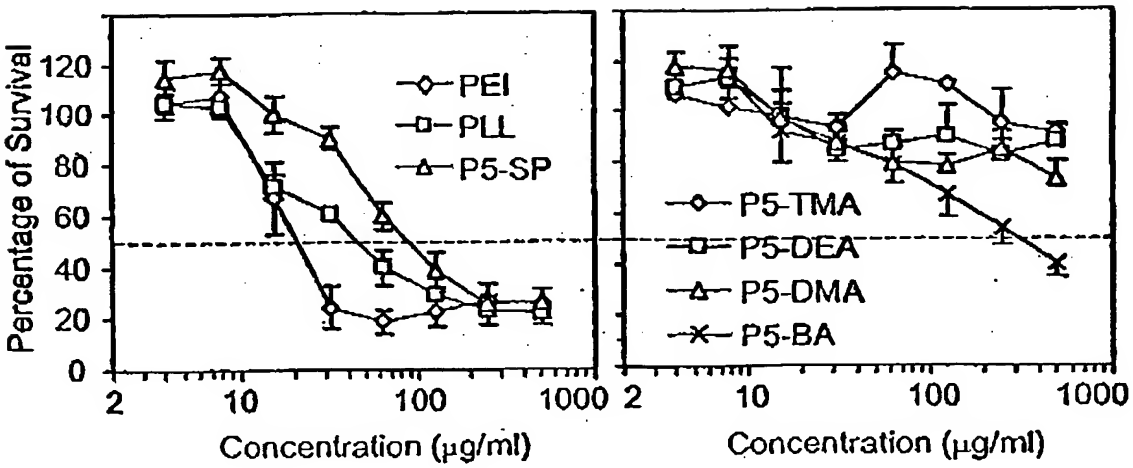


Figure 5.

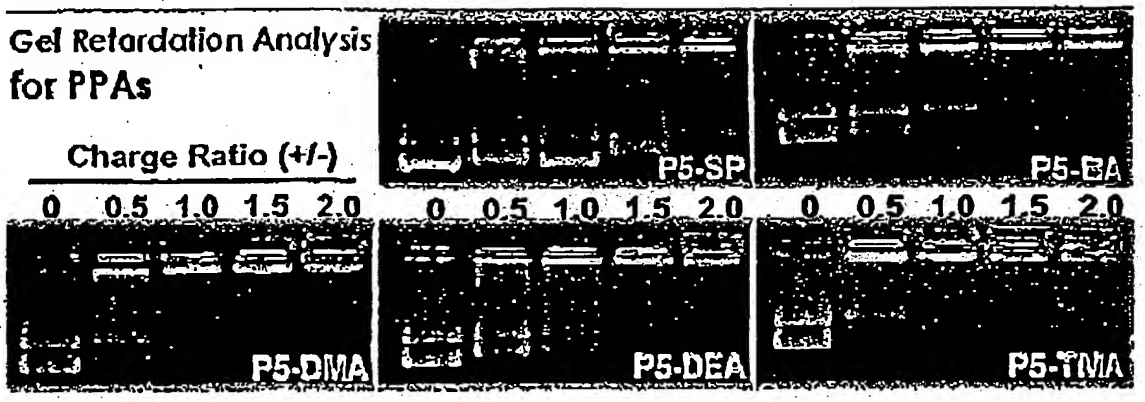


Figure 6.

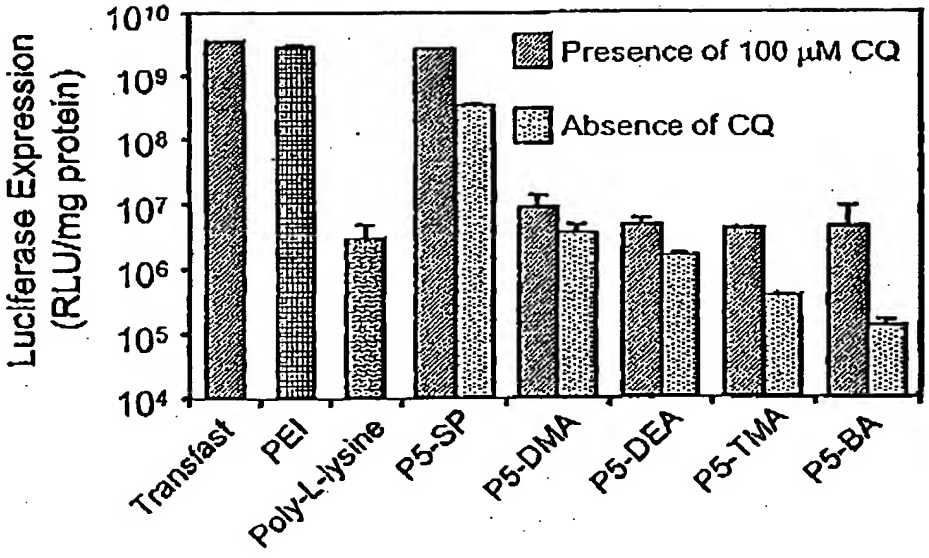


Figure 7.

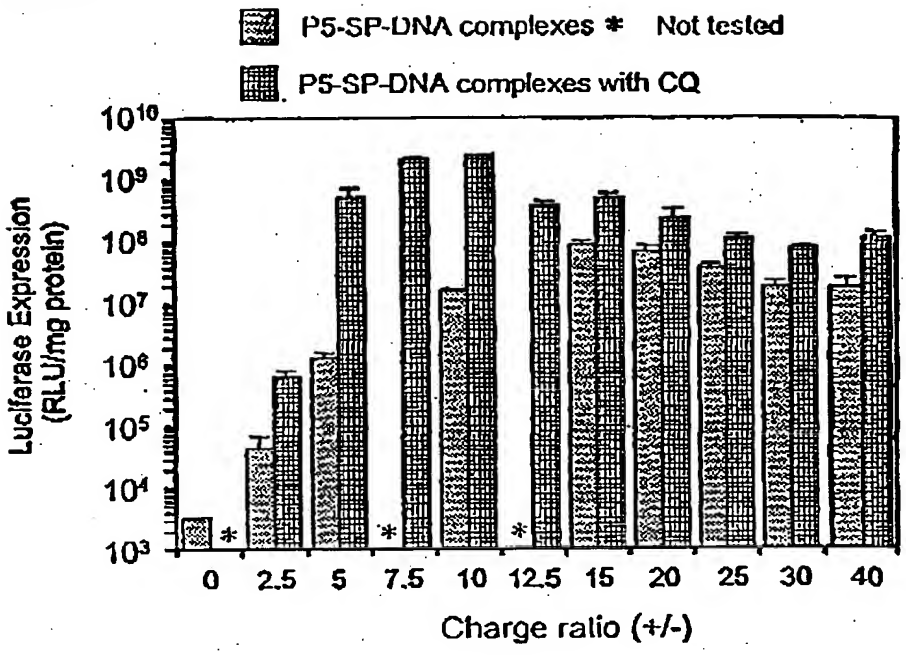


Figure 8.

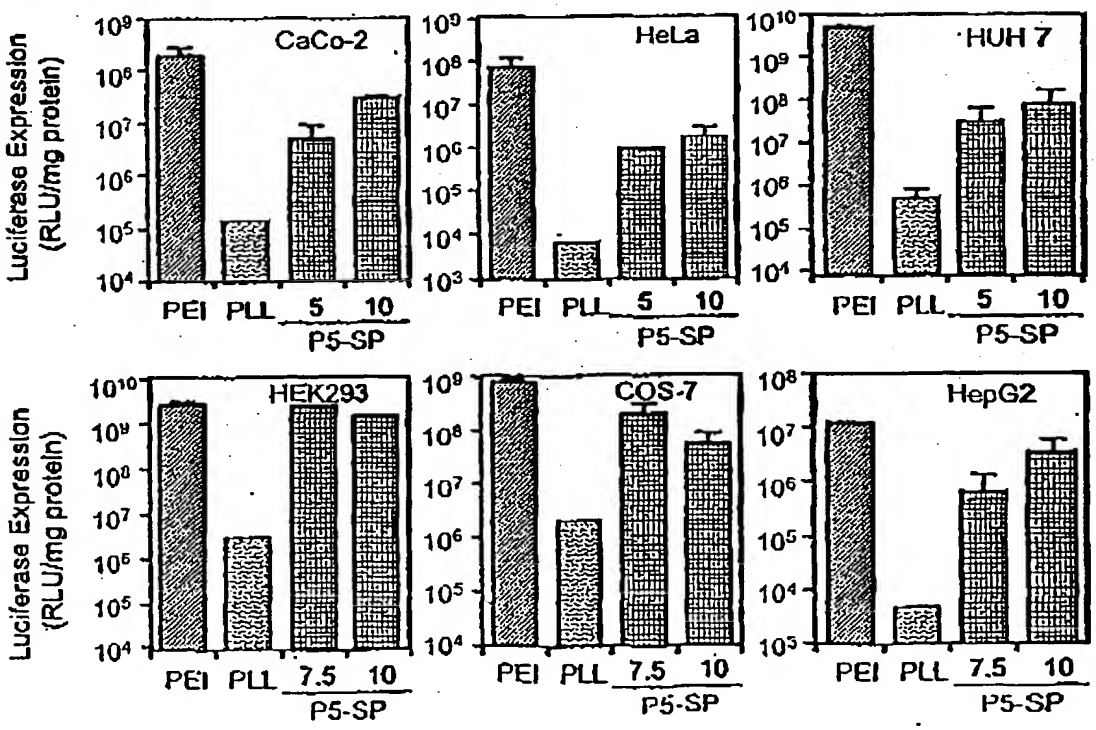
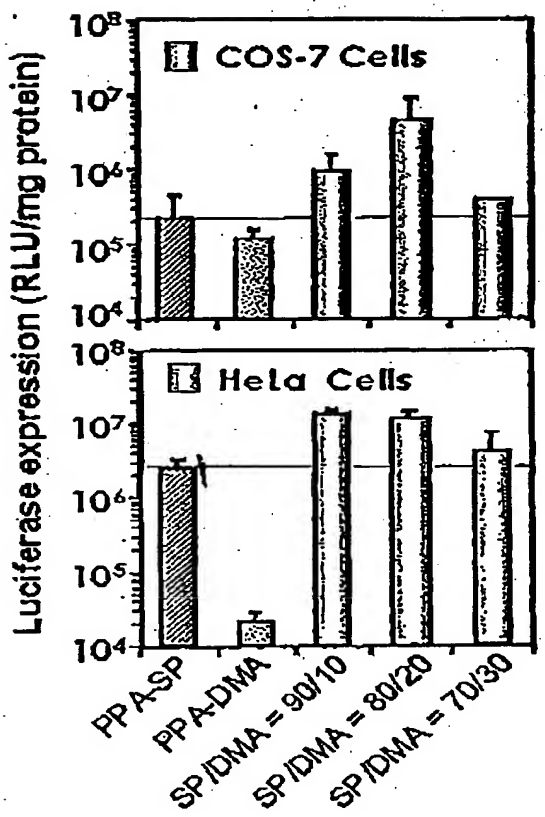


Figure 9


COS-7 Cells
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PPA-DMA
SP/DMA = 90/10
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PTO/SB/01 (08-03)
Approved for use through 07/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☑ Declaration Submitted With Initial Filing **OR** ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	
First Named Inventor	WANG, Jun
COMPLETE IF KNOWN	
Application Number	Express Mail EV 311274159 US
Filing Date	November 13, 2003
Art Unit	
Examiner Name	

I hereby declare that:

Each inventor's residence, mailing address, and citizenship are as stated below next to their name.

I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

BIODEGRADABLE POLYPHOSPHORAMIDATES FOR CONTROLLED RELEASE OF BIOACTIVE SUBSTANCES

(Title of the Invention)

the specification of which

☑ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) ☐ as United States Application Number or PCT International Application Number ☐ and was amended on (MM/DD/YYYY) ☐ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? Yes	Certified Copy Attached? No
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

PTO/SB/01 (08-03)
Approved for use through 07/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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DECLARATION — Utility or Design Patent Application

Direct all correspondence to: ☑ Customer Number: 33717 *OR* ☐ Correspondence address below

Name

Address

City	State	ZIP

Country	Telephone	Fax

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Jun	WANG

Inventor's Signature

Date

Residence: City	State	Country	Citizenship
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Mailing Address: 720 Rutland Avenue
729 Ross Building

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Baltimore	Maryland	21205	U.S.A.

NAME OF SECOND INVENTOR: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Hai-Quan	MAO

Inventor's Signature

Date

Residence: City	State	Country	Citizenship
Singapore	Singapore	Singapore	China

Mailing Address: Block 60 West Coast Crescent
#04-01 West Bay Condominium

City	State	ZIP	Country
Singapore	Singapore	128040	Singapore

☐ Additional inventors or a legal representative are being named on the _____ supplemental sheet(s) PTO/SB/02A or 02LR attached hereto.

PTO/SB/02A (08-03)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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DECLARATION

ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 1 of 1

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Kam Weng	LEONG		
Inventor's Signature		Date	
Residence: City Ellicott City	State Maryland	Country U.S.A.	Citizenship U.S.A.
Mailing Address 10242 Breconshire Road			
Mailing Address			
City Ellicott City	State Maryland	Zip 21042	Country U.S.A.

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Inventor's Signature			
Residence: City	State	Country	Citizenship
Mailing Address			
Mailing Address			
City	State	Zip	Country

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Inventor's Signature	Date		
Residence: City	State	Country	Citizenship
Mailing Address			
Mailing Address			
City	State	Zip	Country

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 21 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference ZB/2002/642	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/SG02/00091	International filing date *(day/month/year)* 14 May 2002	(Earliest) Priority Date *(day/month/year)* 14 May 2001

Applicant

JOHNS HOPKINS SINGAPORE PTE LTD et al.

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

Basis of the report

a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ Certain claims were found unsearchable (See Box I).

3. ☐ Unity of invention is lacking (See Box II).

4. With regard to the title,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the abstract,

☒ the text is approved as submitted by the applicant

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the drawings to be published with the abstract is Figure No. 1

☒ as suggested by the applicant.

☐ None of the figures

☐ because the applicant failed to suggest a figure

☐ because this figure better characterizes the invention

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG02/00091

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: C08G 79/04, A61K 47/48, A61P 21/06, 11/06, 9/10, 1/08, 35/00, 11/02, 1/12, 1/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C08G 79/04, A61K 47/48

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPAT & JAPIO (Search terms: phosphoester, biodegradable)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 194 581 A (LEONG) 16 March 1993 See column 4 line 19 to column 5 line 25, column 6 lines 29-68 and column 7 lines 36-55	1-70
X	US 5 952 451 A (ZHAO) 14 September 1999 See column 4 line 55 to column 6 line 30 and column 16 lines 40-54	1-70
X	US 6 166 173 A (MAO et al.) 26 December 2000 See claims 1, 5, 75 and 78	1-70

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 June 2002	24 JUN 2002

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
E-mail address: pct@ipaustralia.gov.au
Facsimile No. (02) 6285 3929

Authorized officer

ALBERT S. J. YONG
Telephone No : (02) 6283 2160

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG02/00091

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98/46286 A (JOHNS HOPKINS UNIVERSITY SCHOOL OF MEDICINE) 22 October 1998 See claims 1, 30 and 63	1-70
X	WO 98/48859 A (GUILFORD PHARMACEUTICALS INC.) 5 November 1998 See claim 1	1-70
X	WO 99/00446 A (GUILFORD PHARMACEUTICALS INC.) 7 January 1999 See page 8 line 17 to page 10 line 4, claims 1 and 20.	1-11, 21-31
X	WO 00/19976 A (GUILFORD PHARMACEUTICALS INC.) 13 April 2000 See page 11 lines 23-25 and claims 1, 15, 28 and 43.	1-70
X	WO 00/57852 A (GUILFORD PHARMACEUTICALS INC.) 5 October 2000 See page 18 line 21 to page 19 line 32, claims 1 and 17	1-70

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SG02/00091

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5194581	CA	2011171	EP	386757	JP	3128938
		US	5256765				
US	5952451	AU	82611/98	EP	990008	US	6028163
		WO	9900446				
US	6166173	AU	69449/98	BR	9809390	EP	971969
		HU	200001412	NO	994803	NZ	500674
		WO	9844020	US	6376644		
WO	9846286	AU	71206/98	US	5912225	US	6238687
WO	9848859	AU	71771/98	BR	9809017	EP	980269
		HU	200001299	NO	995301	PL	336596
WO	9900446	AU	82611/98	EP	990008	US	6028163
		US	5952451				
WO	200019976	AU	62833/99	EP	1117441	US	6153212
WO	200057852	AU	200037625	BR	200009213	CZ	20013260
		EP	1185249	NO	20014662		

END OF ANNEX

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference ZB/2002/642	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. PCT/SG02/00091	International Filing Date *(day/month/year)* 14 May 2002	Priority Date *(day/month/year)* 14 May 2001

International Patent Classification (IPC) or national classification and IPC

Int. Cl.[7] C08G 79/04, A61K 47/48, A61P 21/06, 11/06, 9/10, 1/08, 35/00, 11/02, 1/12, 1/10

Applicant

JOHNS HOPKINS SINGAPORE PTE LTD et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

   [X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheet(s).

3. This report contains indications relating to the following items:

   - I [X] Basis of the report
   - II [ ] Priority
   - III [ ] Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV [ ] Lack of unity of invention
   - V [X] Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI [ ] Certain documents cited
   - VII [ ] Certain defects in the international application
   - VIII [ ] Certain observations on the international application

Date of submission of the demand	Date of completion of the report
13 December 2002	21 August 2003
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer ALBERT S. J. YONG Telephone No. (02) 6283 2160

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SG02/00091

I. Basis of the report

1. With regard to the elements of the international application:*

- [ ] the international application as originally filed.
- [X] the description, pages 1-29, 44(abstract) as originally filed,
  pages , filed with the demand,
  pages , received on with the letter of
- [X] the claims, pages , as originally filed,
  pages , as amended (together with any statement) under Article 19,
  pages , filed with the demand,
  pages 30-34 , received on 14 August 2003 with the letter of 14 August 2003
- [X] the drawings, pages 45-49 , as originally filed,
  pages , filed with the demand,
  pages , received on with the letter of
- [ ] the sequence listing part of the description:
  pages , as originally filed
  pages , filed with the demand
  pages , received on with the letter of

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:
- [ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- [ ] the language of publication of the international application (under Rule 48.3(b)).
- [ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:
- [ ] contained in the international application in written form.
- [ ] filed together with the international application in computer readable form.
- [ ] furnished subsequently to this Authority in written form.
- [ ] furnished subsequently to this Authority in computer readable form.
- [ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- [ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. [X] The amendments have resulted in the cancellation of:
- [ ] the description, pages
- [X] the claims, pages 35-43
- [ ] the drawings, sheets/fig.

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item I and annexed to this report*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SG02/00091

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1-27	YES
	Claims	NO
Inventive step (IS)	Claims 1-27	YES
	Claims	NO
Industrial applicability (IA)	Claims 1-27	YES
	Claims	NO

2. Citations and explanations (Rule 70.7)

CITATIONS

D1. US 5194581

D2. US 5952451

D3. US 6166173

D4. WO 98/46286

D5. WO 98/48859

D6. WO 99/00446

D7. WO 00/19976

D8. WO 00/57852

NOVELTY (N) AND INVENTIVE STEP (IS)

Claims 1-27: The claimed invention relates to a positively charged biodegradable polyphosphoramidate that is capable of forming a complex with negatively charged bioactive macromolecules.

The closest art, D1, discloses a biodegradable poly(phosphoester) whereby a therapeutic agent capable of being released in a physiological environment is covalently attached to polymer backbone as a pendant group or forms part of the backbone itself. The citation does not teach the formation of complexes. Hence, the claims are novel and inventive.

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G. Turner

G. Turner

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PATENT

Receipt is hereby acknowledged for the following at Mail Stop PCT (DO/EO/US), Commissioner for Patents, Alexandria, VA 22313.

Express Mail Label No.	EV 311274159 US
Title:	Biodegradable Polyphosphoramidates for Controlled Release of Bioactive Substances
Applicant	WANG, Jun; MAO, Hai-Quan; LEONG, Kam Weng
Client:	Tan Rajah and Cheah
Docket:	Tan Rajah Cheah 010202
Date of Deposit:	November 13, 2003

US NATIONAL PHASE PATENT APPLICATION

Transmittal Letter to DO/EO/US Concerning a Filing Under 35 U.S.C. § 371 and duplicate copy; $654.00 – authorization to charge deposit account; Declaration, unexecuted (total 3 pages); copy of International Application as filed; copy of International Application with Amendments to the IPER incorporated; extra set of drawings; International Search Report PCT/ISA/210; and International Preliminary Examination Report PCT/IPEA/409

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